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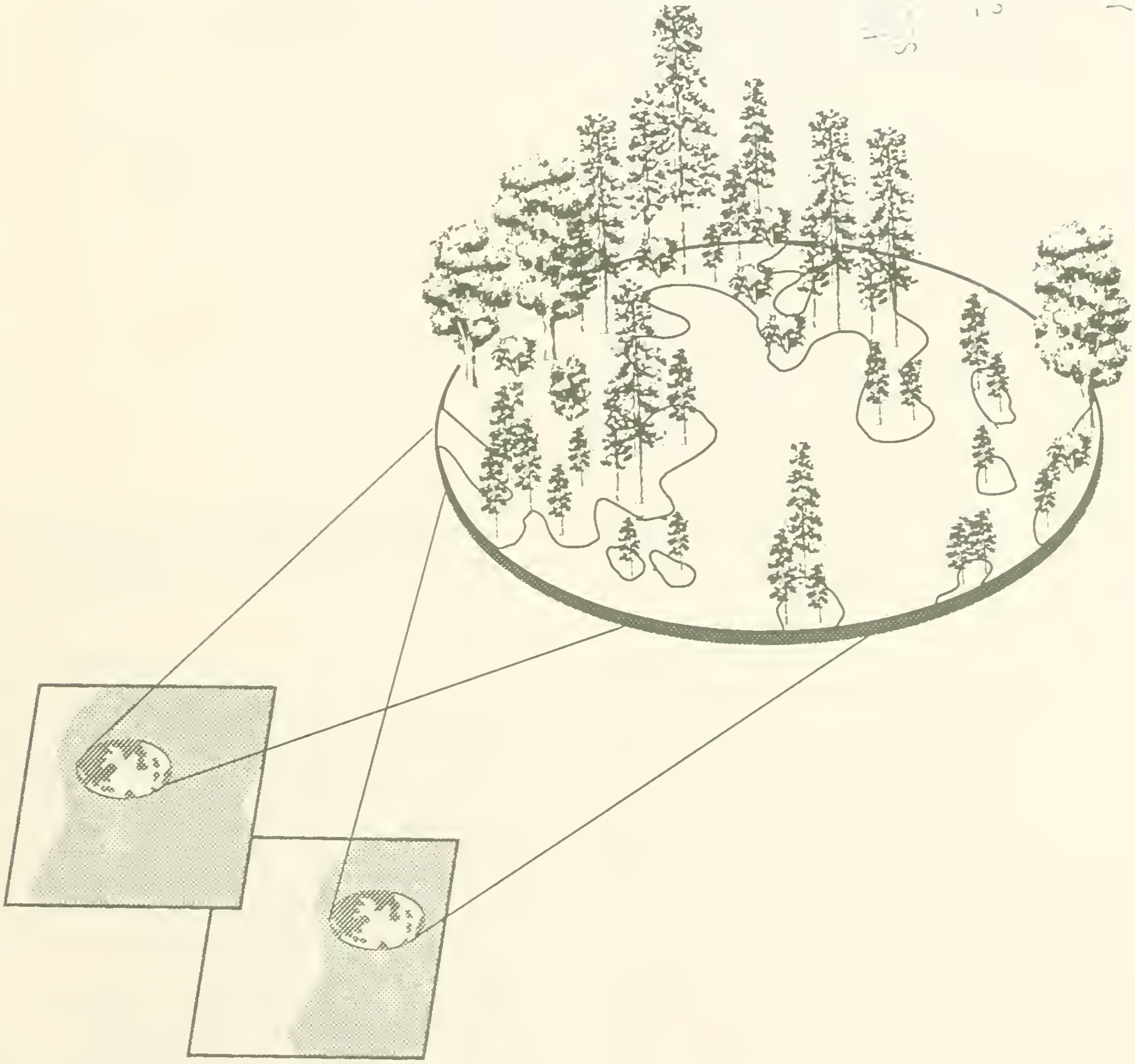

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RESEARCH SUMMARY

Two methods of overstory canopy cover assessment currently in use by Forest Survey—field photo and calculated—were compared to two alternate methods, stereo-plotted and line-intercept. The line-intercept method was used as the control. The number of transects needed to obtain a reasonable estimate of overstory canopy cover using the line-intercept method was between 6 and 8. However, the line-intercept method is time consuming, so if there are time constraints, then field photo estimates of cover are the preferred alternative for Forest Survey.

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INTRODUCTION

Crown canopy cover is among the most widely used measures of abundance of plant species because it is not biased by the size or distribution of individuals (Daubenmire 1968). Crown canopy cover—simply referred to as cover—is usually expressed in terms of percentage of ground covered by a vertical projection of a plant's crown. Cover is commonly broken down into two major components: overstory or tree cover, and understory cover. Overstory cover data have many purposes. For example: predicting woody plant composition, tree volume, or potential forage production; assessing wildlife habitat; and evaluating forest pest damage.

The Forest Survey Research Work Unit of the Intermountain Research Station conducts forest inventories over much of the Rocky Mountain area. Forested land of both timberland and woodland species is inventoried. Timberland includes species such as Douglas-fir (*Pseudotsuga menziesii*), ponderosa pine (*Pinus ponderosa*), and western larch (*Larix occidentalis*) that are traditionally used by the forest products industry. Woodland includes pinyon (*Pinus* spp.), juniper (*Juniperus* spp.), and other shrublike tree species.

One of the variables required from forest inventories is overstory cover. For a given site it can be used to assess distribution patterns within a region and to devise or validate relationships between overstory cover and other resource attributes on a site.

THE PROBLEM

Forest Survey uses two methods of overstory cover estimation: ocular field photo estimation and calculations based on crown dimensions. The problem is that the two methods sometimes yield widely varying values. Inventory crews ocularly estimate overstory crown cover in the field using aerial photos and on-site interpretation. These ocular estimates are recorded in direct percentages. Overstory cover is also calculated from crown measurements taken on trees sampled by field crews on Forest Survey plots.

A single, overall method needs to be chosen for consistency and efficiency. As a means of comparison with the two methods already described, two more intensive cover estimation methods were employed—the line-intercept method (Canfield 1941) and stereo-plotted cover digitized from photos. The purpose of this study is to compare the two Forest Survey methods of obtaining cover with the two alternatives, to determine the most efficient procedure for use by Forest Survey.

METHODS

The study was conducted on a subsample of Forest Survey plots in north-central New Mexico in the pinyon-juniper, ponderosa, mixed conifer, and spruce-fir forest types. The line-intercept method was chosen as the control for comparison with the other methods. It was considered the most accurate method because the intercepts were measured on the ground rather than ocularly estimated from photos, thus eliminating the subjectivity of identifying tree crowns from shadows and other illusionary effects.

Using the line-intercept method, overstory cover was measured on an acre surrounding each of 10 woodland and 10 timberland Forest Survey field plots. The proportion of the area covered by a species was determined by the length of transect intersected by that species or life form, divided by the total length of the transect. This method is most often used in understory cover estimation. It was more difficult to apply to overstory cover as height-to-tree crowns increased. Twenty 100-foot transects were systematically placed at each location (fig. 1), parallel to the slope of the plot. This number of transects was considered excessive but useful in determining the number of transects necessary for adequate evaluation.

Overstory cover was transferred from aerial photographs (1:16,000 to 1:24,000 scale) using a stereo-plotting instrument. Cover was plotted for 1 acre, at a mean scale of 1 inch equal to 200 feet (fig. 1). This stereo-plotted cover was then digitized using a two-axis digitizer with an associated error factor of one-hundredth inch. Tree cover and interspaces were digitized separately, then combined and compared to the total area of an acre. This checking procedure identified errors that were then adjusted for. The mean adjustment factor was less than 1.3 percent.

Calculated cover values were taken from the New Mexico Forest Survey field inventory data base (U. S. Department of Agriculture 1986). The values were calculated from maximum and minimum crown dimensions measured by field crews on trees sampled with a variable plot method on timberland plots and on all trees on smaller woodland plots. The sampled cover was then expanded to represent the stand being sampled. These different sampling strategies for woodland and timberland are important but were not considered part of this study and will not be discussed further in this paper. Field photo estimates of cover were made on-site by an experienced estimator for each of the 20 study plots, similar to usual Forest Survey practice.

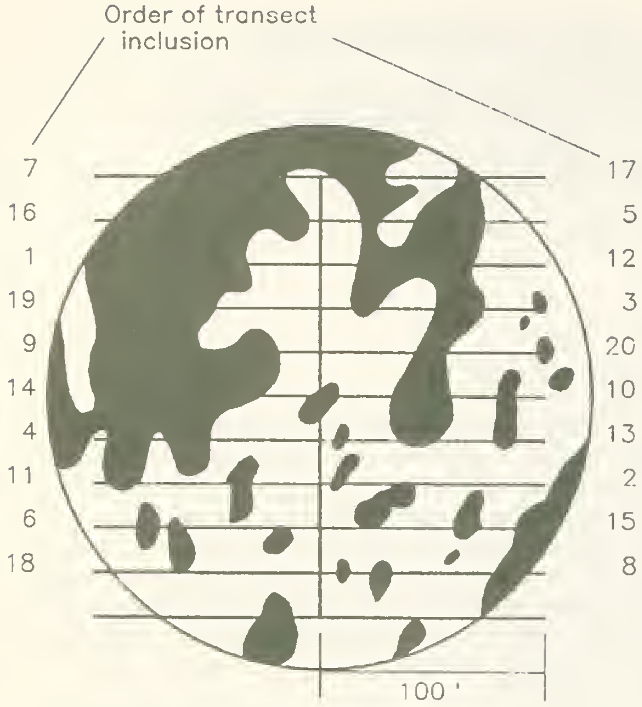

Figure 1—Map of stereo-plotted and digitized cover from 1-circular-acre timberland plot, with transect pattern overlaid. The numbers listed along the outside edges of the transect pattern illustrate the order of transect cover inclusion into the running mean.

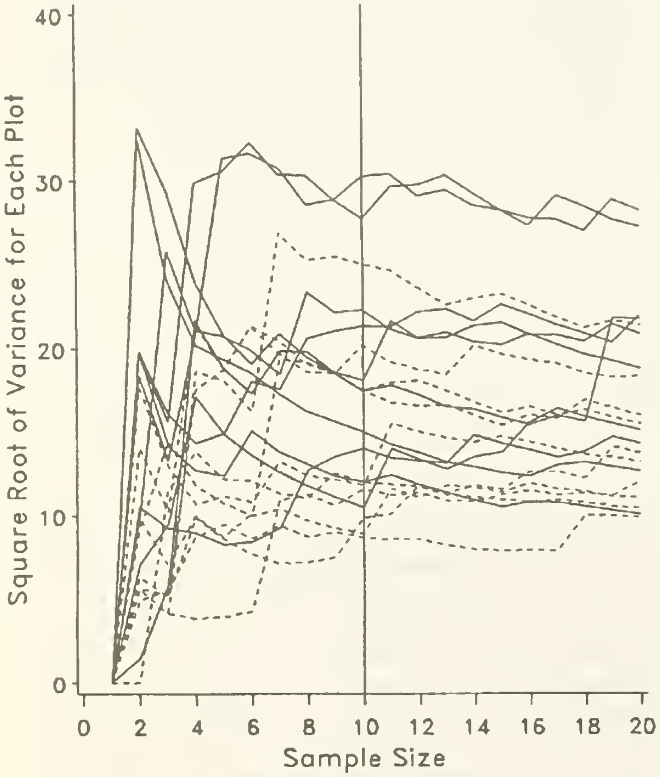

Figure 2—Square root of variance plotted against number of transects sampled—timberland (solid lines) and woodland (dashed lines). Vertical line denotes the sample size where variances more or less stabilize.

The line-intercept method, used as the control, was compared to the other methods in two ways. The first mode of comparison used 95 percent confidence intervals computed around the control and centered on a zero mean difference. A method was considered significantly different from the control if its difference from the control fell outside the confidence interval. Confidence intervals were calculated using the *t*-statistic and the variance of cover among 10 line-intercept transects. The choice of 10 transects for each plot seemed appropriate because the variance stabilized after 10 transects (fig. 2). The formula used was:

$$\text{Confidence Interval} = 0 \pm 2.93\sqrt{\text{VAR}/10}$$

where VAR = variance of the first 10 transects (diagrammed in fig. 1) for each plot.

The second mode of comparison was overall mean difference of each method from the control. To avoid confusion when speaking of differences between values taken in percentage, hereafter no units will be mentioned. In other words, a difference between 20 and 30 percent is listed as 10.

Determination of the optimum number of transects needed to obtain reasonable cover estimates was made using running means (Kershaw and Looney 1985). The basic premise behind the running mean method is that an adequate sample size has been reached when additional samples do not significantly affect the mean. Transects were included in the running means in a random order, which is listed in figure 1.

RESULTS AND DISCUSSION

Cover estimates obtained with the four methods for each of the 10 timberland and 10 woodland locations are presented in table 1. Included are the results of the confidence intervals placed around the line-intercept control to evaluate the differences between each method and the control. On the average, using any method, cover estimates fell outside the 95 percent confidence interval placed around the line-intercept values about half the time. Stereo-plotted estimates of cover fell outside the 95 percent confidence interval less often than field photo estimates of cover, which in turn fell outside less often than calculated cover estimates. In general, woodland cover estimation was better than timberland cover estimation using any method. This could be because of the taller, multistoried nature of timberland versus the shorter, single-storied woodland.

Table 2 includes the overall mean difference between line-intercept and the other three methods, and the standard deviation of the differences. The field photo estimate had the lowest mean difference from line-intercept on all plots, but all estimates had similar standard errors. Negative mean differences for field photo estimates may indicate an overestimation bias (table 2).

Table 1—Percentage line-intercept cover (control) and other percentage cover estimates—calculated from crown measurements, ocularly estimated from photos in the field, and stereo-plotted and digitized from photos—for each study plot

Forest type	Line-intercept (control)	Stereo-plotted	Field photo estimate	Calculated
	Percent			
Timberland	24	12 **	25	11 **
Timberland	25	11	14	2 **
Timberland	31	41 **	44 **	20 **
Timberland	39	40	55 **	20 **
Timberland	40	21 **	28 **	29
Timberland	51	57	58	67
Timberland	51	42	51	30 **
Timberland	56	25 **	39 **	45
Timberland	62	39 **	52 **	43 **
Timberland	67	88 **	87 **	35 **
Woodland	8	4	2 **	7
Woodland	9	5	12	8
Woodland	16	9	15	5 **
Woodland	25	14 **	21	15 **
Woodland	27	24	34	12 **
Woodland	37	28	35	21 **
Woodland	43	42	62 **	30 **
Woodland	43	31	20 **	39
Woodland	43	37	42	53
Woodland	55	72 **	78 **	29 **

** Cover estimates whose differences from the control fell outside a 95 percent confidence interval placed around the control.

Table 2—Mean difference and variance of the differences between line-intercept percentage cover values and other percent cover estimates

	Cover estimation method	Mean difference	$\sqrt{\text{Variance}}$
		Percent	
Timberland only	Calculated	14	13
	Photo estimated	–1	13
	Stereo-plotted	7	16
Woodland only	Calculated	9	10
	Photo estimated	–2	13
	Stereo-plotted	4	8
Timberland and woodland combined	Calculated	12	11
	Photo estimated	–1	13
	Stereo-plotted	6	13

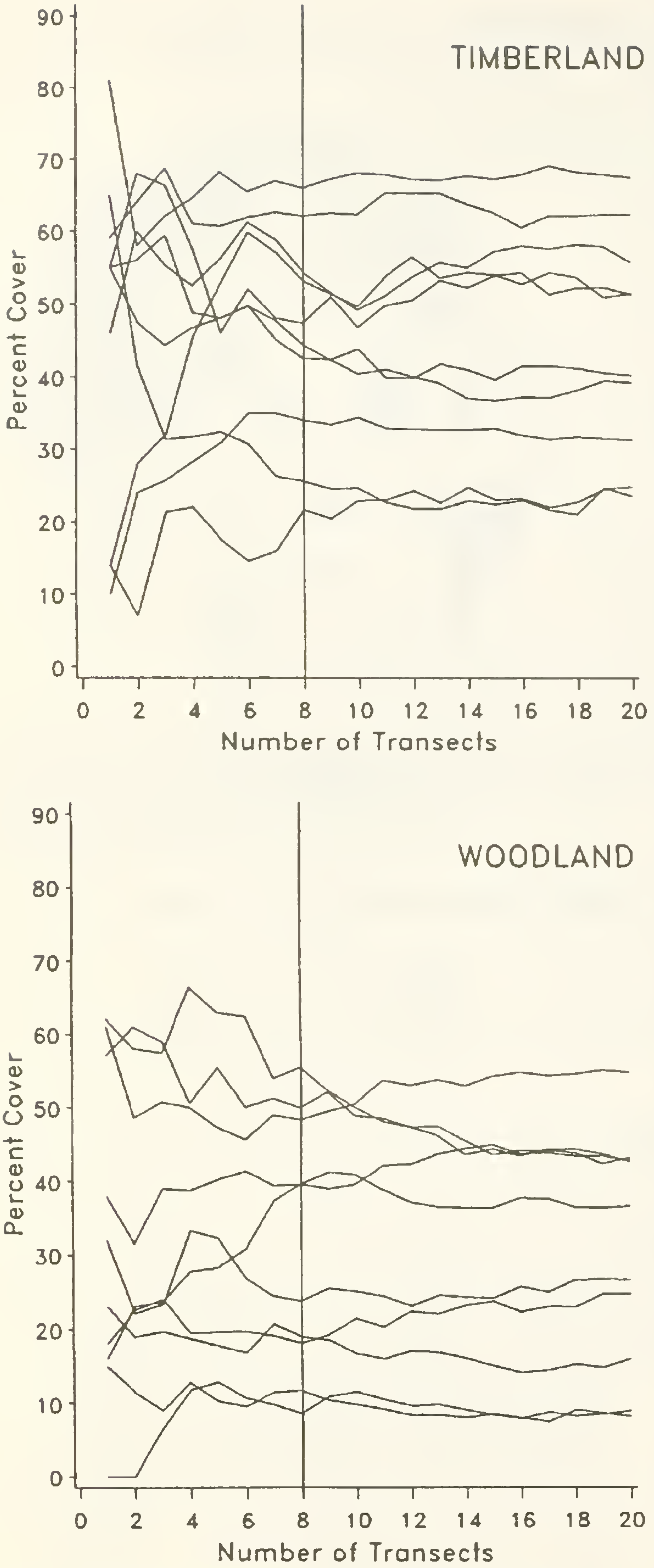

Figure 3—Relation of mean line-intercept cover to number of transects sampled, by timberland and woodland. The Y-axis is mean cover for all 20 transects (control) for each of 10 timberland and 10 woodland plots. Vertical lines denote the optimum number of transects.

Graphical analysis was used to determine the optimum number of transects for cover estimation on an acre (fig. 3). Apparent stabilization of the running mean lines in general occurred at about seven or eight transects; fewer for woodland plots at low cover and for timberland plots at high cover.

Arbitrary standards have been set by requiring that a sample be within 5 or 10 percent of some maximum sample (Mueller-Dombois and Ellenberg 1974). In this study, the average number of transects needed to be within 10 percent of the mean of all 20 transects, on all 20 plots, was six. Therefore, between six and eight transects should give an adequate sample of overstory cover in most cases.

CONCLUSIONS

On the average, using any method, cover estimates fell outside the 95 percent confidence interval placed around the line-intercept values about half the time (table 1). The field photo estimates fell outside the confidence interval fewer times than the other Forest Survey method, calculated cover. Field photo estimates also had the lowest overall mean difference in percentage (–1) from the line-intercept control, as compared with a mean difference of 6 for stereo-plotted cover and 12 for calculated cover.

The stereo-plotted cover method, which was used in this study as an alternative means of comparison, is too time consuming and takes too much specialized equipment to be used by Forest Survey on each plot. The results of this method fell outside the confidence interval fewer times than the field photo estimates but had a greater mean difference from the line-intercept control.

The calculated cover method proved to be the most different from the control in terms of the confidence interval and overall mean difference. Some of this difference can be attributed to different plot sizes and tree sampling techniques not discussed in this paper.

The line-intercept method, which we have assumed is the most accurate cover evaluation method, could be used on Forest Survey plots but is still much more time consuming than photo estimation. After a sample size of eight, the number of transects made little difference when compared to the mean of 20 transects. In general, woodland cover estimation was better than timberland cover estimation using any method.

If time constraints do not permit line-intercept transect layout, field photo estimates of cover are the best alternative for Forest Survey. Other researchers have advocated photo estimation. Vora (1988) found no significant difference between ocular and spherical densiometer cover estimates and recommended ocular estimates in some cases. Vales and Bunnell (1988) showed that different observers' ocular estimations of forest overstory cover were similar. Photo estimates done on-site are probably better than photo estimates done in the office because changes since the photos were taken and areas in question such as shadows and understory vegetation can be corrected for ocularly. Adequate training is needed, of course, to ensure that consistent, accurate estimates are obtained.

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KEYWORDS: overstory cover, line-intercept, field photo estimates, stereo-plotted cover

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